RHIC Polarimetry: Status and Plans

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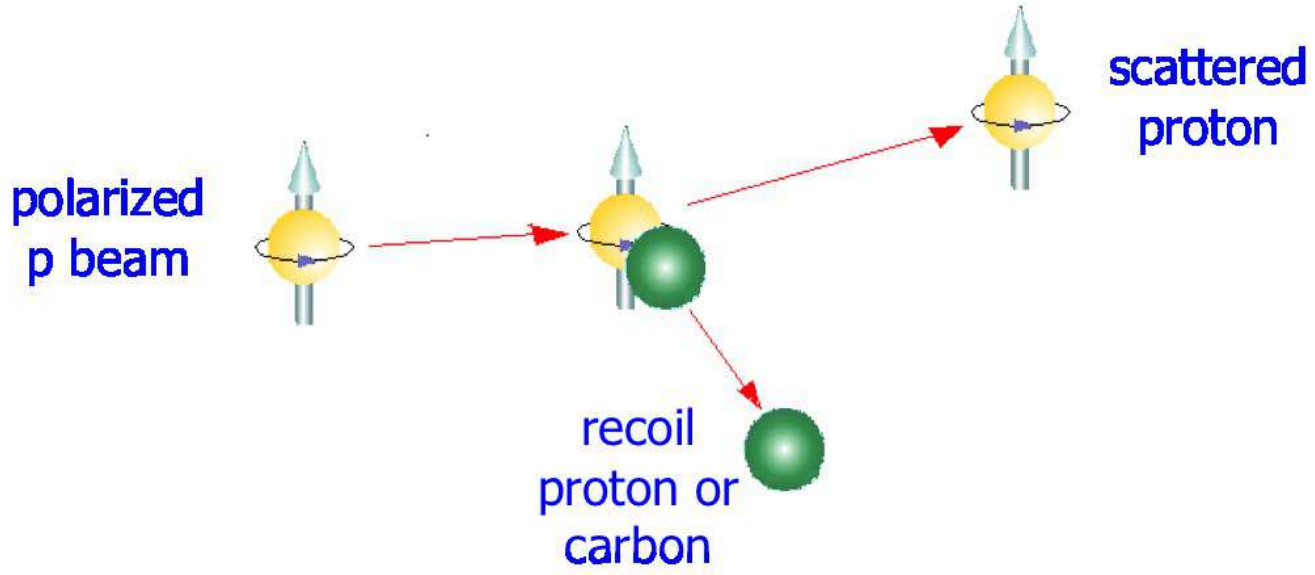
June 12, 2012

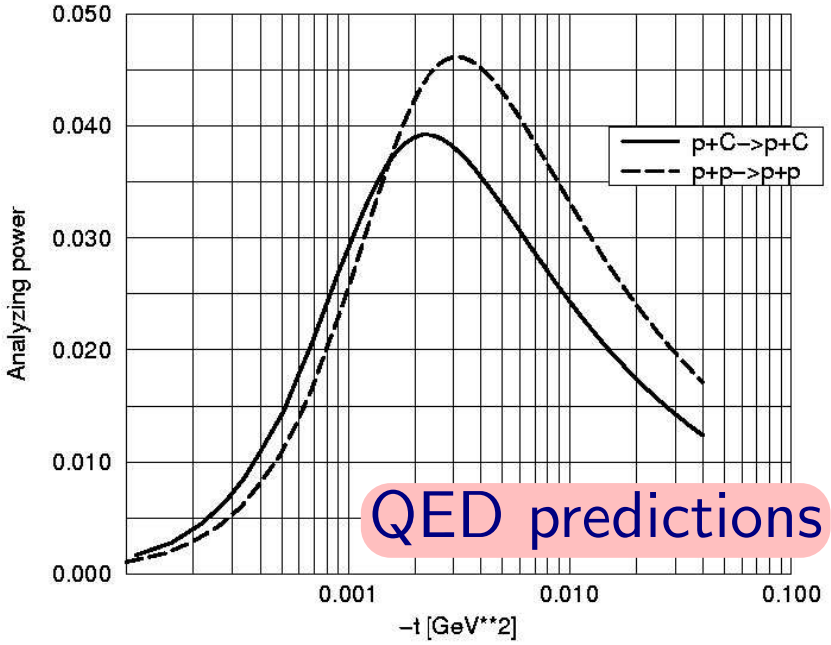
Outline

- Measuring polarization at RHIC
- Overview of RHIC polarimeters
- Hardware configuration in Run 12
- Issues experienced in Run 12
- Run 12 results
- Summary and plans for Run 13

CNI Polarimetry at RHIC

- Particle spin in hadron interactions gives rise to asymmetric yields w.r.t. spin direction
- In elastic scattering maximum asymmetry A_N is expected in the region of Coulomb-Nuclear interference where EM and strong amplitudes are comparable in strength





In absence of hadronic spin-flip amplitude analyzing power A_N is exactly calculable from QED

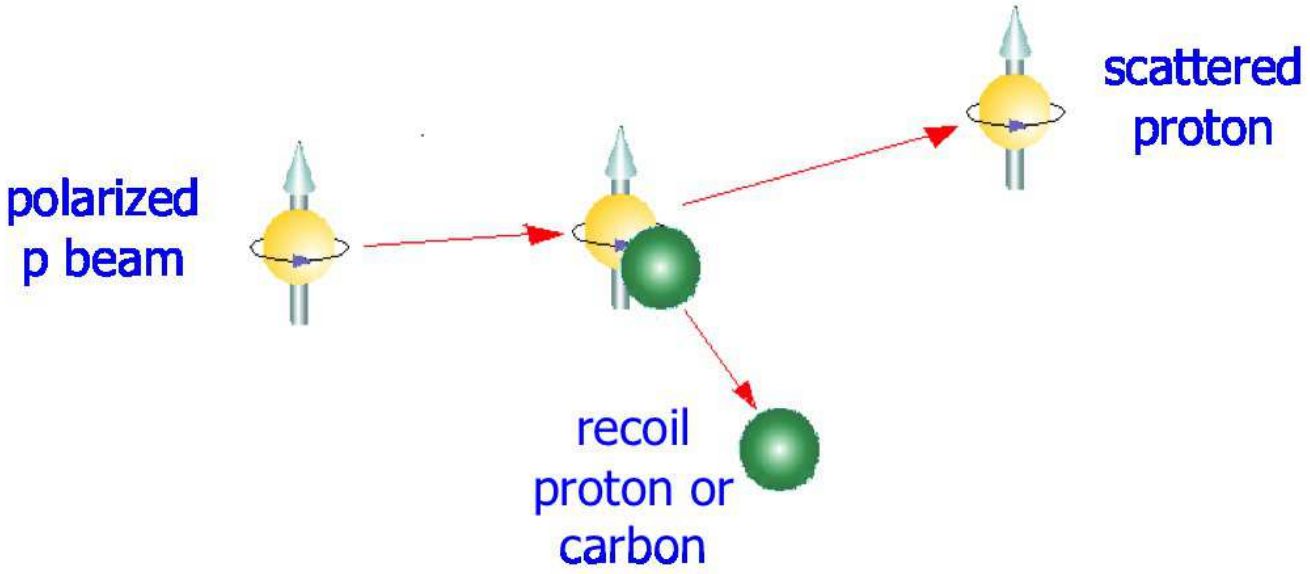
- **Measured polarization $P = \varepsilon / A_N$**

CNI Polarimetry at RHIC

- Particle spin in hadron interactions gives rise to asymmetric yields w.r.t. spin direction

- In elastic scattering maximum asymmetry A_N is expected in the region of Coulomb-Nuclear interference where EM and strong amplitudes are comparable in strength

$$\varepsilon = \frac{N_L - N_R}{N_L + N_R}$$



$$\varepsilon = \frac{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} - \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}{\sqrt{N_L^{\uparrow} N_R^{\downarrow}} + \sqrt{N_L^{\downarrow} N_R^{\uparrow}}}$$

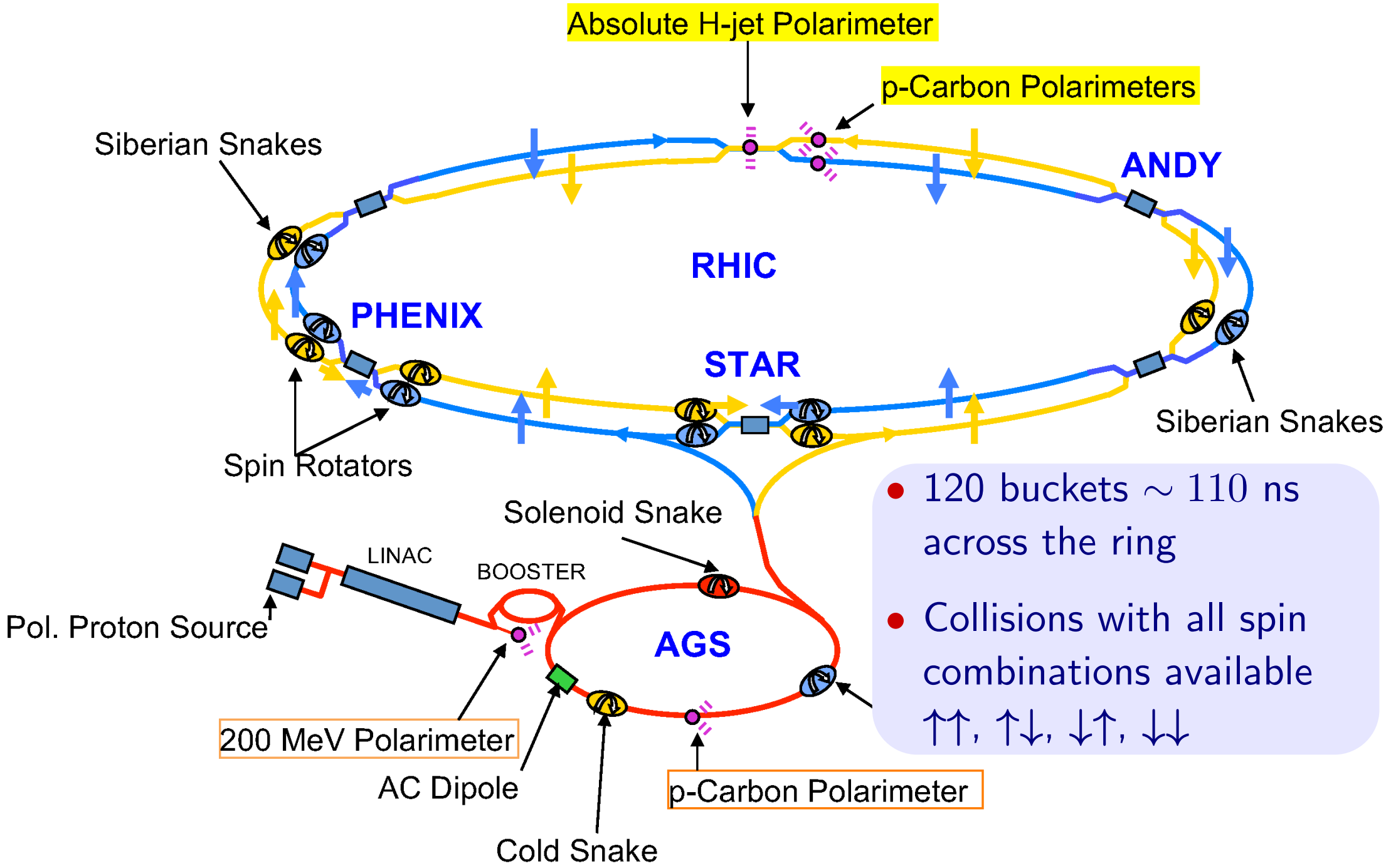
- In general, knowledge of A_N is required

- **Measured polarization $P = \varepsilon / A_N$**

Requirements on RHIC Polarimetry

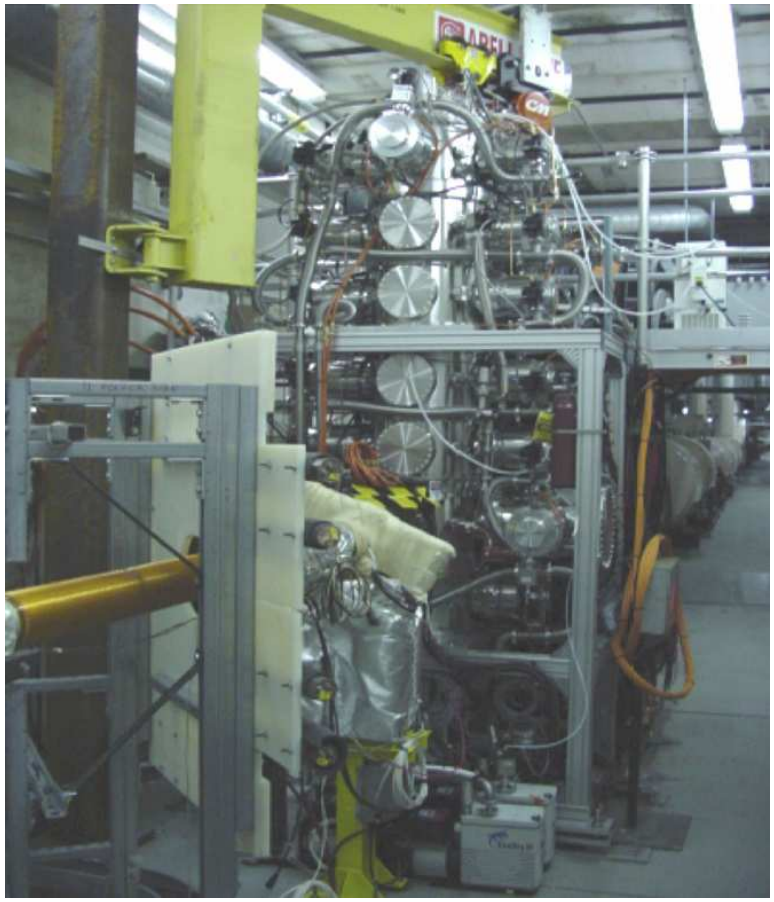
- Fast feedback for polarized beam setup, tune and development
- Precise beam polarization measurements for RHIC experiments
  - Non-destructive polarization measurement
  - Operation over a wide range of beam energies from injection at 24 to 255 GeV
  - Polarization lifetime or decay during a fill
  - Beam polarization profile for proper re-weighting of polarization in collisions

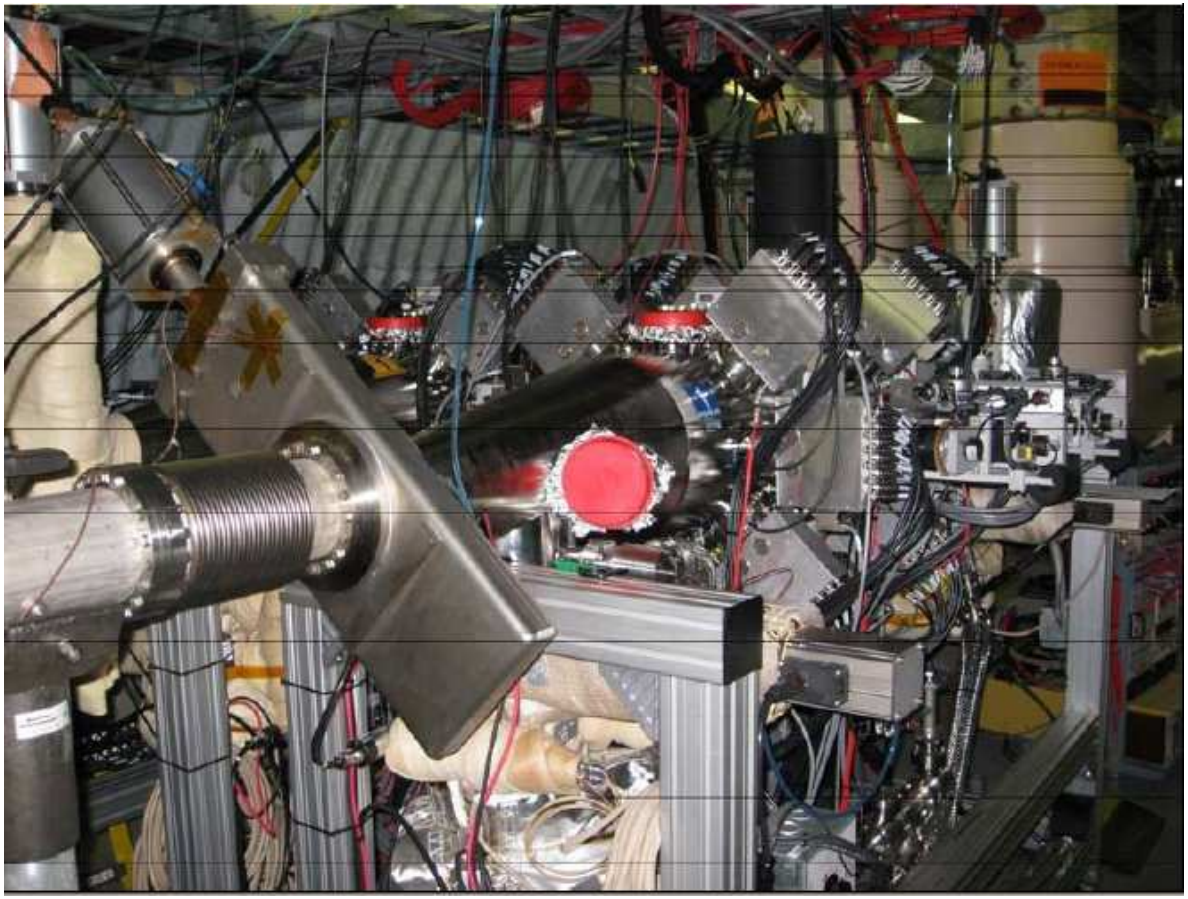
Accelerator Complex and Polarimeters



- 120 buckets ~ 110 ns across the ring
- Collisions with all spin combinations available $\uparrow\uparrow, \uparrow\downarrow, \downarrow\uparrow, \downarrow\downarrow$

Measurement Strategy

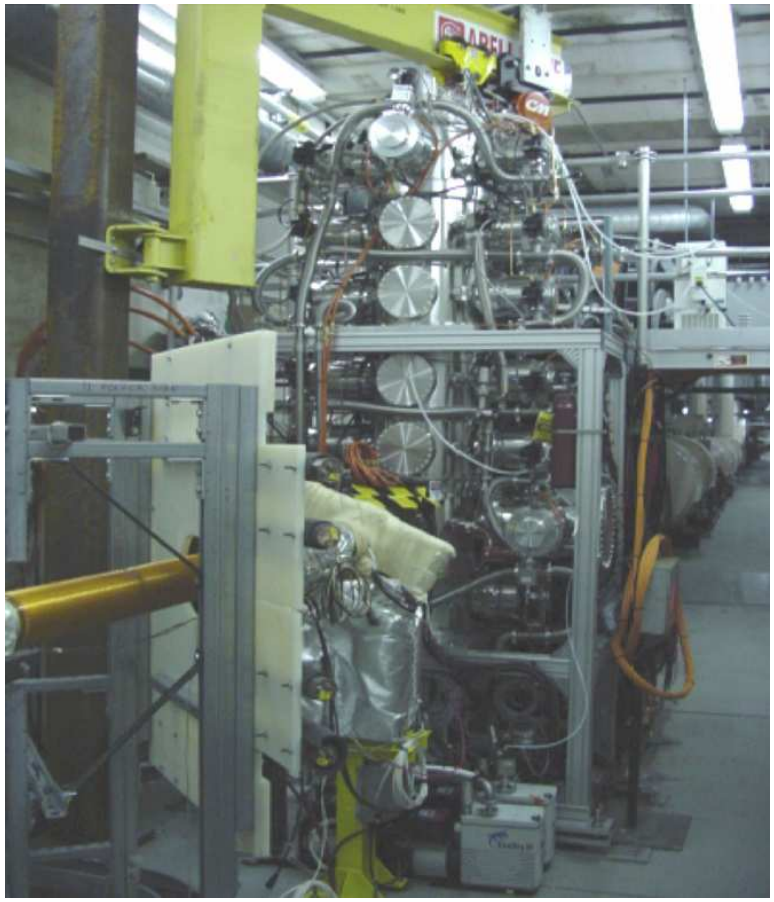


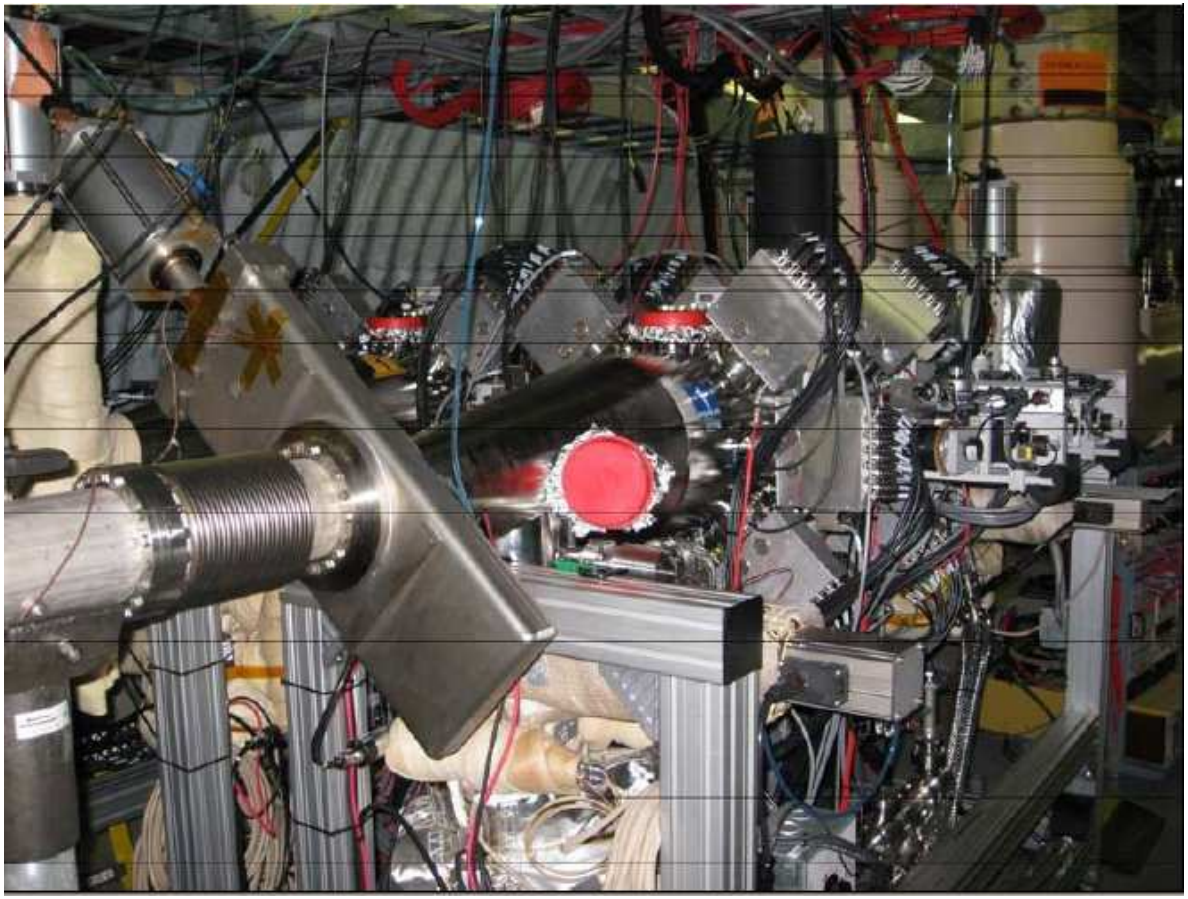


- **Hydrogen jet (H-jet) polarimeter**
  - **Low stat. measurement**
  - Continuous operation throughout a fill
  - Provides **average** absolute polarization over the fill ($\sim 8-10$ hours)

- **Two p-Carbon polarimeters in each ring**
  - **High stat. measurement**
  - About four 2-minute measurements per fill
  - Bunch and fill polarization for the experiments
  - Vertical and horizontal beam polarization profiles
  - Polarization decay in fill

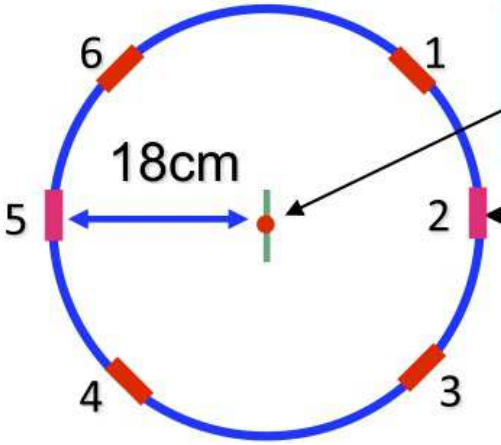
Targets



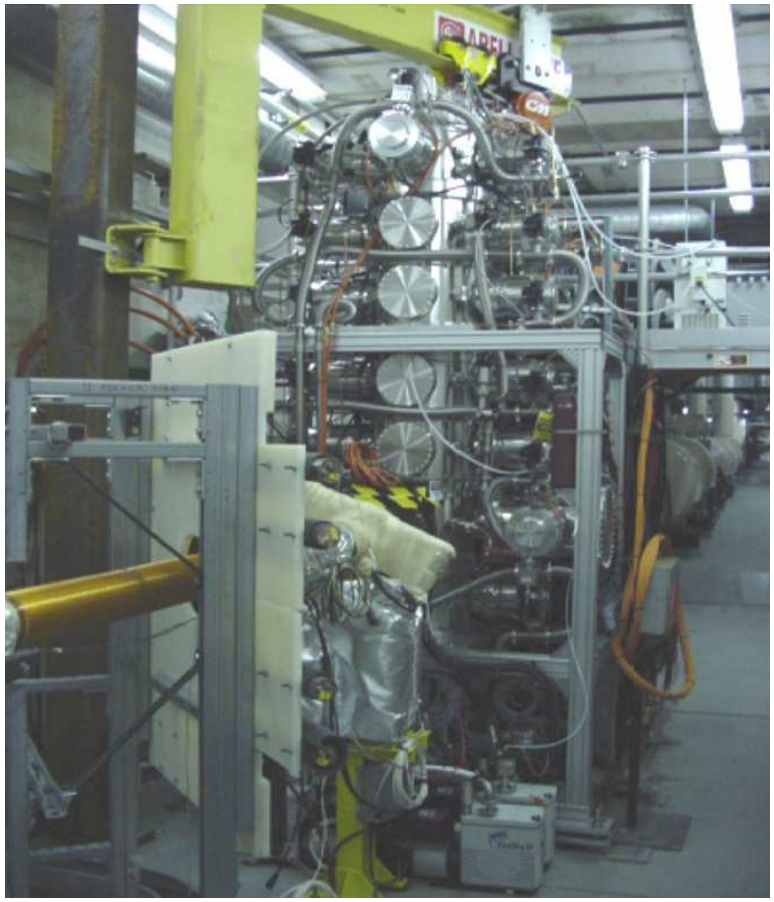


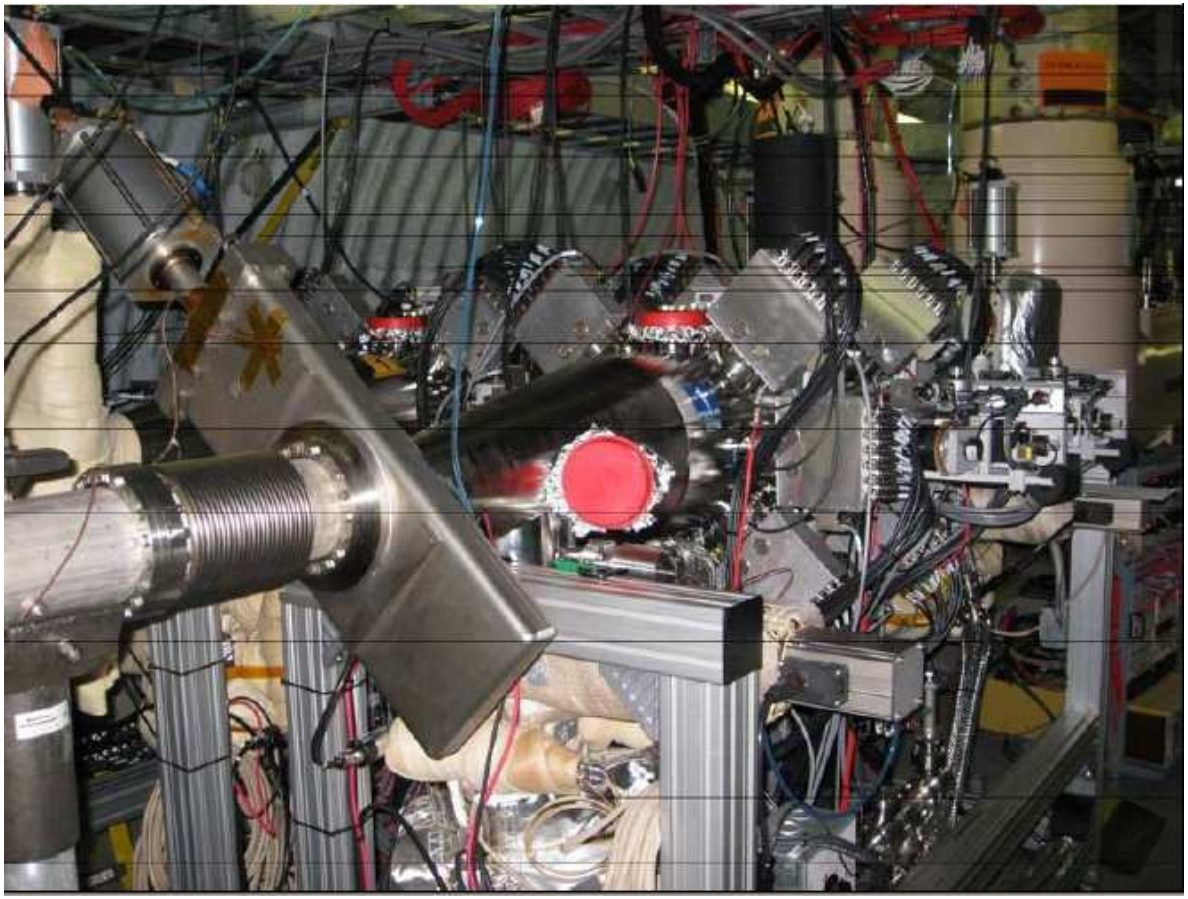
- **H-jet polarimeter**
  - **Vertical** polarized ($\approx 92\%$) hydrogen jet $\sim 6-7$ mm in diameter
  - Target polarization cycles $\uparrow /0/ \downarrow$ every 300/30/300 seconds

- **p-Carbon polarimeters**
  - Ultra thin carbon ribbon 2.5 cm $\times$ 10 μm $\times$ 25 nm
  - **Vertical** and **horizontal** targets



Detectors





- **H-jet and p-Carbon polarimeters**
  - Strip silicon detectors
  - Energy calibration is done with α sources
  - Record energy and ToF of every hit above a threshold

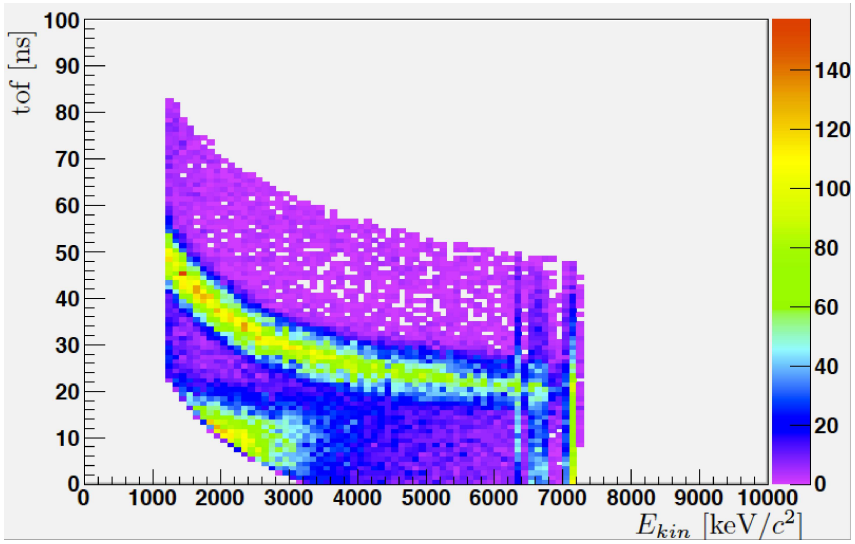
Configuration in Run 12

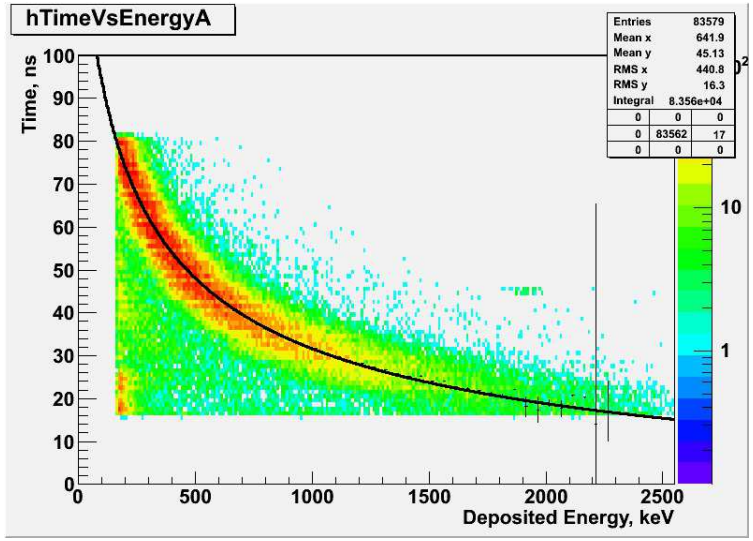
- **Detectors:** Most of the detectors were reused from Run 11
  - Observed no significant degradation due to radiation
- **Targets:** Fabricated according to standard technique as in Run 11
- Few special targets and experimental detectors (different orientation, manufacturer) were placed in only one p-Carbon polarimeter (Blue-2)

Challenges in Run 12

- **RF noise** overlapping with signal was observed in some channels/detectors
  - Added shielding
  - Found and terminated open cables next to p-Carbon
  - Noise reduced in subsequent fills
  - Implemented algorithm to cut noise channels
- High rate of carbon **target loss**
  - Conserved targets by reducing the number of measurements
  - All target replaced twice

Event Kinematics





- Elastic events are identified with the non-relativistic relation:

$$E_{\text{meas}} + E_{\text{loss}} = \frac{m}{2} \times \frac{L^2}{(t_{\text{meas}} + t_0)^2}$$

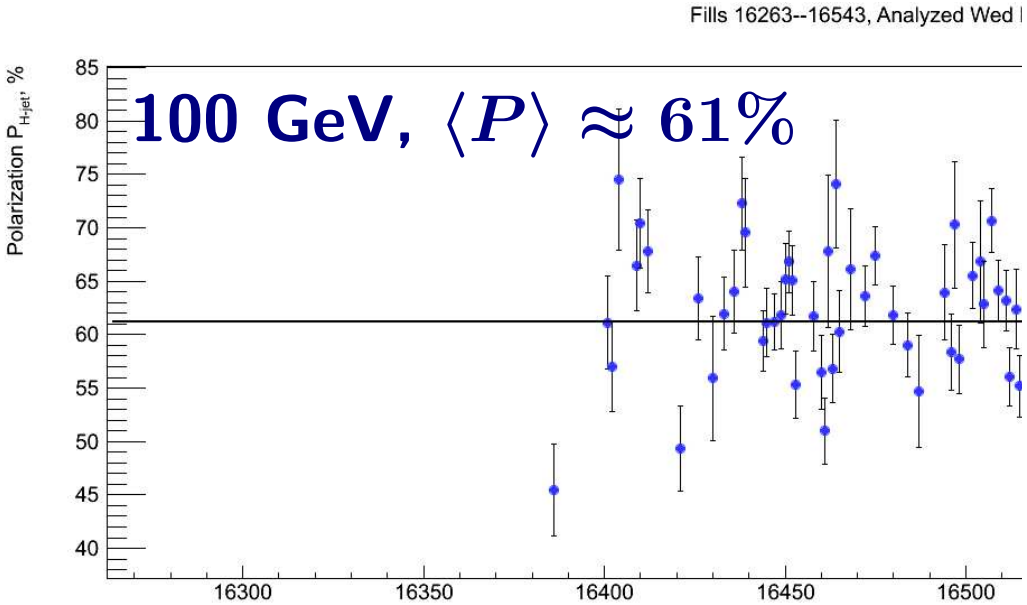
where E_{loss} and t_0 are calibration constants extracted from the fit to the data

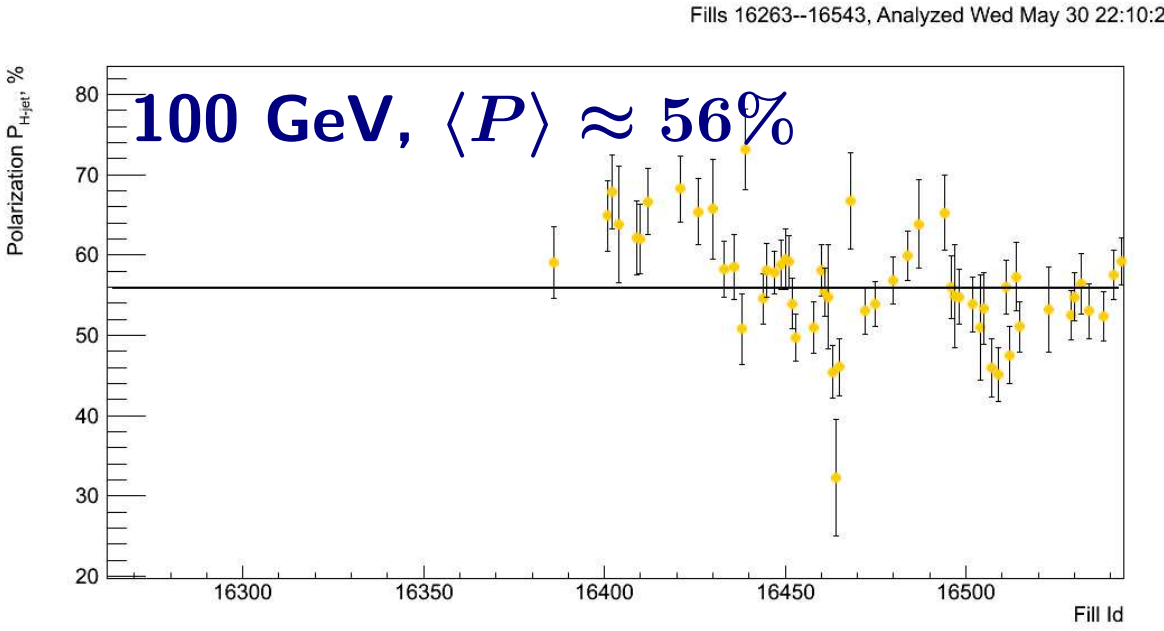
- **H-jet polarimeter**
  - The beam and the target are both protons:

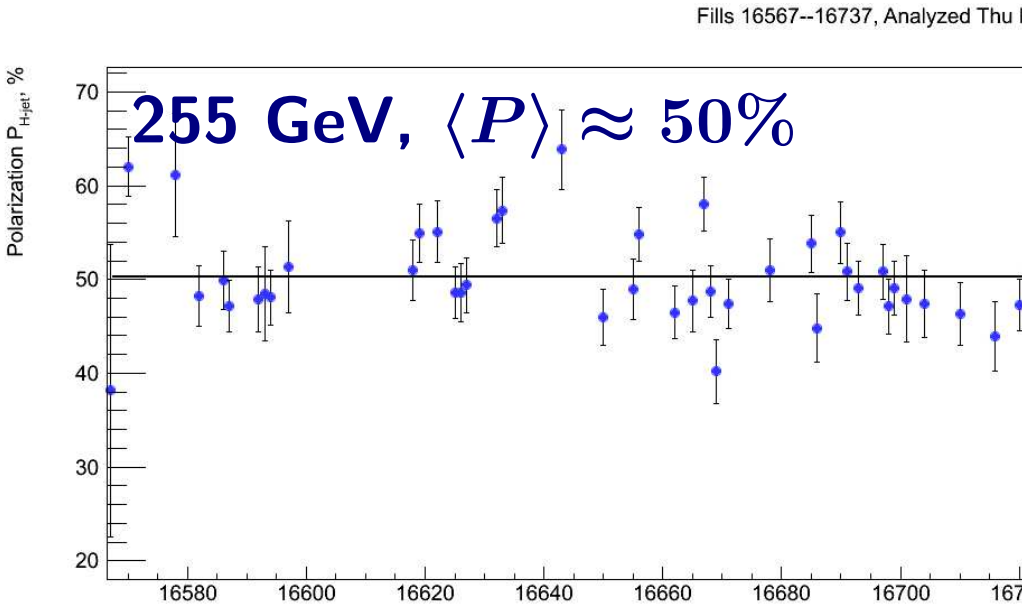
$$P = \frac{\varepsilon}{A_N}, \qquad P_{\text{beam}} = -\frac{\varepsilon_{\text{beam}}}{\varepsilon_{\text{target}}} \times P_{\text{target}}$$

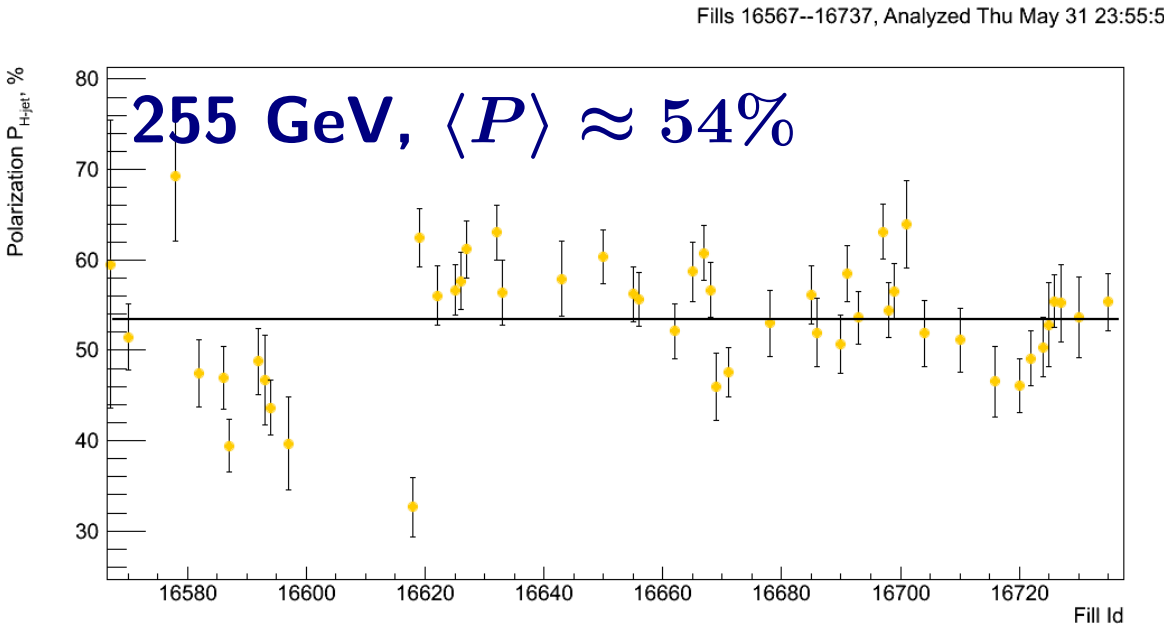
  - **No need to know A_N!**
- **p-Carbon polarimeter**
  - A_N is known from previous measurements
  - Normalized to H-jet over many fills

Fill Polarization by H-Jet



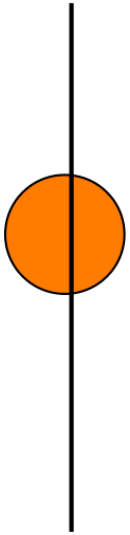


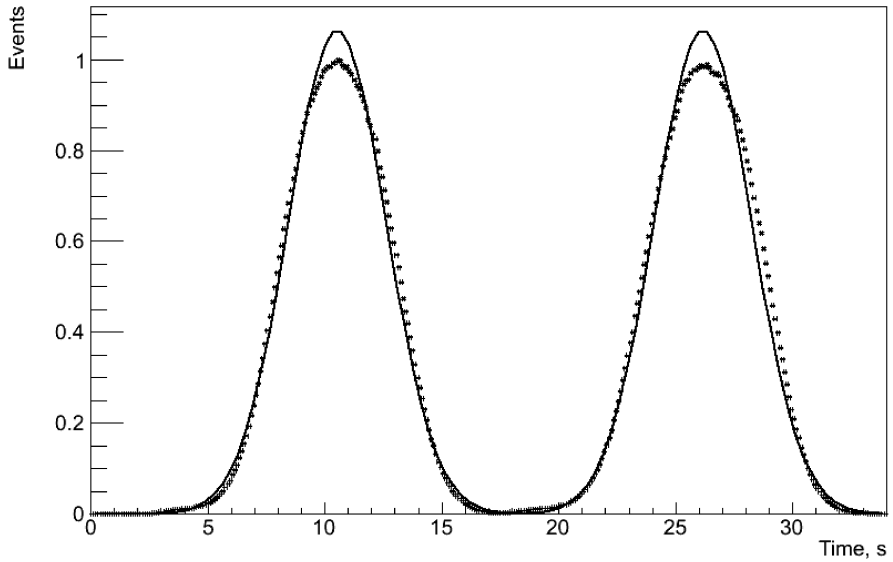


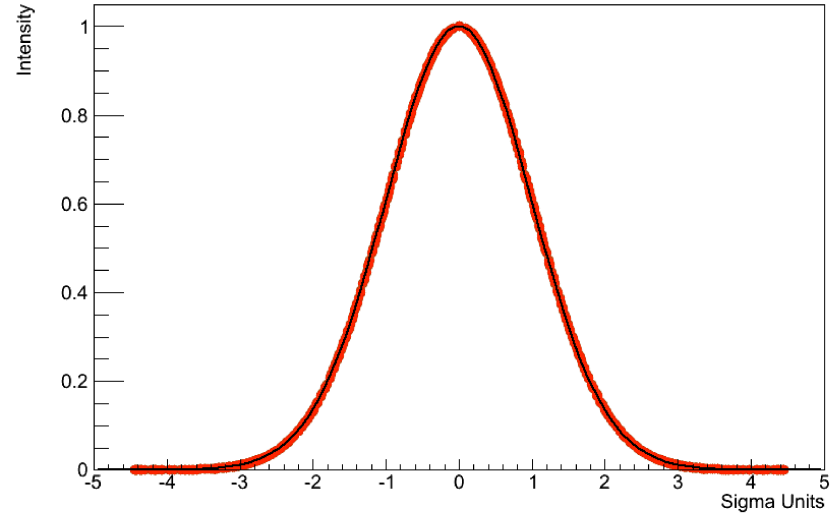


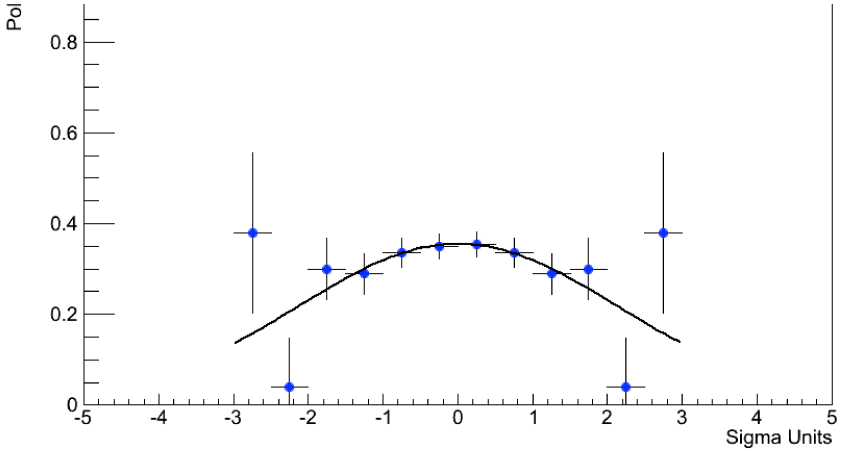
Polarization Profile

- Polarization profile can be described by
  - Center value P_0
  - Profile parameter $R = \frac{\sigma_I^2}{\sigma_P^2}$
  - $R = 0$ if $\sigma_P = \infty$ *i.e.* no Pol. profile
- Intensity profile is assumed to have a gaussian shape with $\sigma = 1$





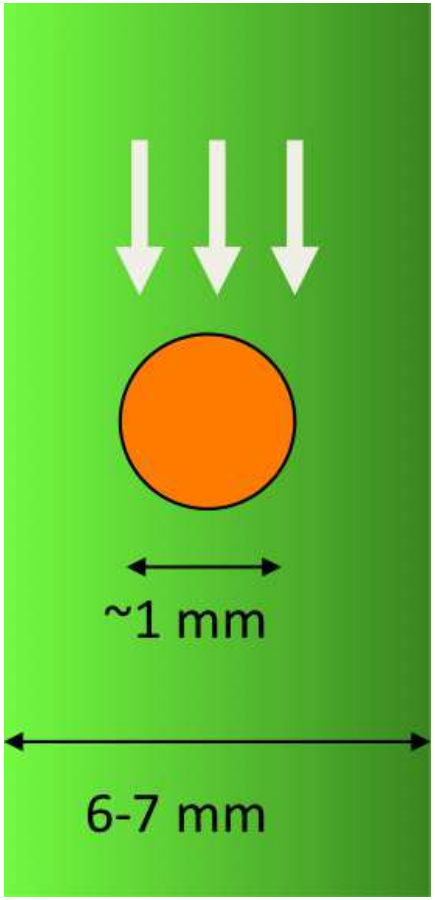




Polarization Profile

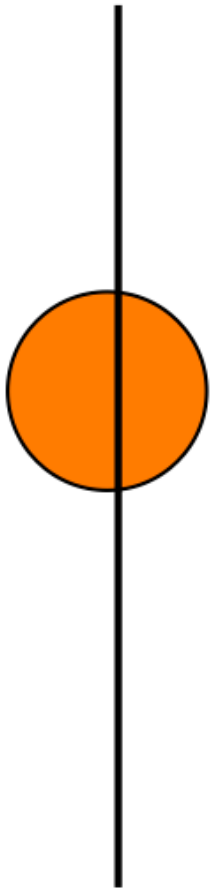
- Because of polarization changing across the beam the average polarization seen by polarimeters and experiments is different

H-Jet



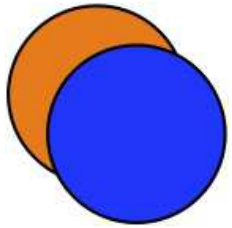
$$\overline{P} = \frac{\int P(x,y) I(x,y) dxdy}{\int I(x,y) dxdy}$$

p-Carbon



$$\overline{P}_{\text{sweep}} = \overline{P}$$

Beam collisions



$$\overline{P}_{\text{coll}} = \frac{\int P(x,y) I^{(\text{B})}(x,y) I^{(\text{Y})}(x,y) dxdy}{\int I^{(\text{B})}(x,y) I^{(\text{Y})}(x,y) dxdy}$$

Polarization in Beam Collisions

- $R_v \approx R_h$
- R in Run 11 $\approx R$ in Run 12 ≈ 0.20
- Assuming gaussian polarization and intensity profiles:

$$\overline{P}_{\text{coll}} = \overline{P} \times k_{\text{coll}} \qquad \text{where} \qquad k_{\text{coll}} \approx \left(1 + \frac{1}{2}R\right).$$

- Final results by fill

  `http://www.phy.bnl.gov/cnipol/fills/`

RHIC Polarimetry Results by Fill

Run Period: Run 12

Fill: Use "%" to match any number of characters, use "_" to match

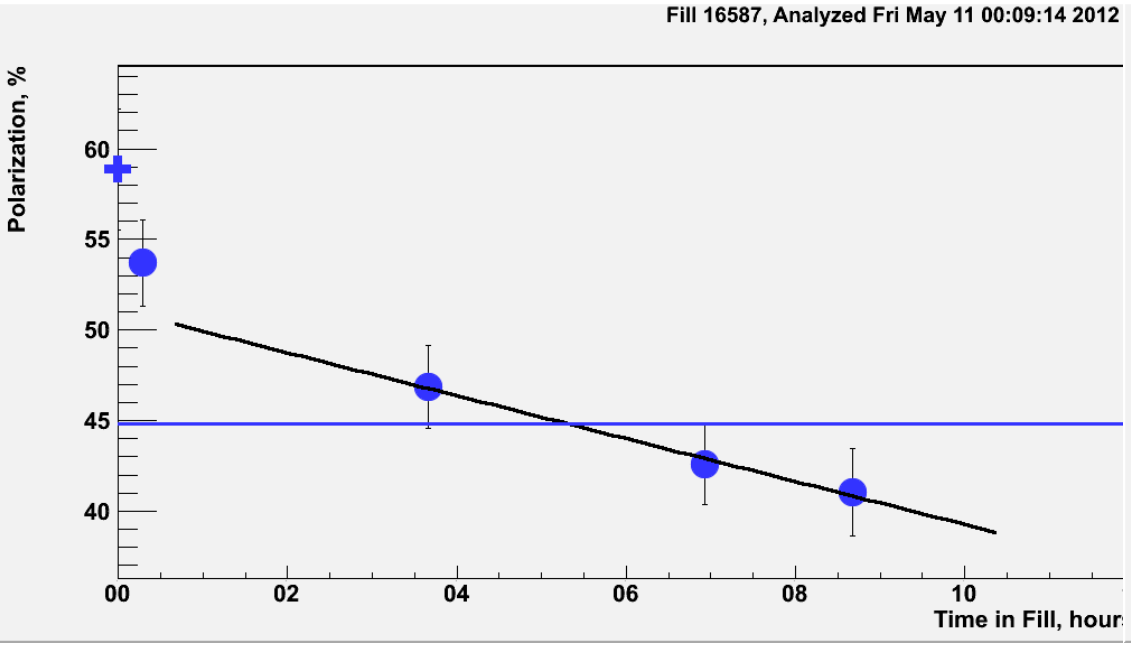
Type: phys Flattop Energy:

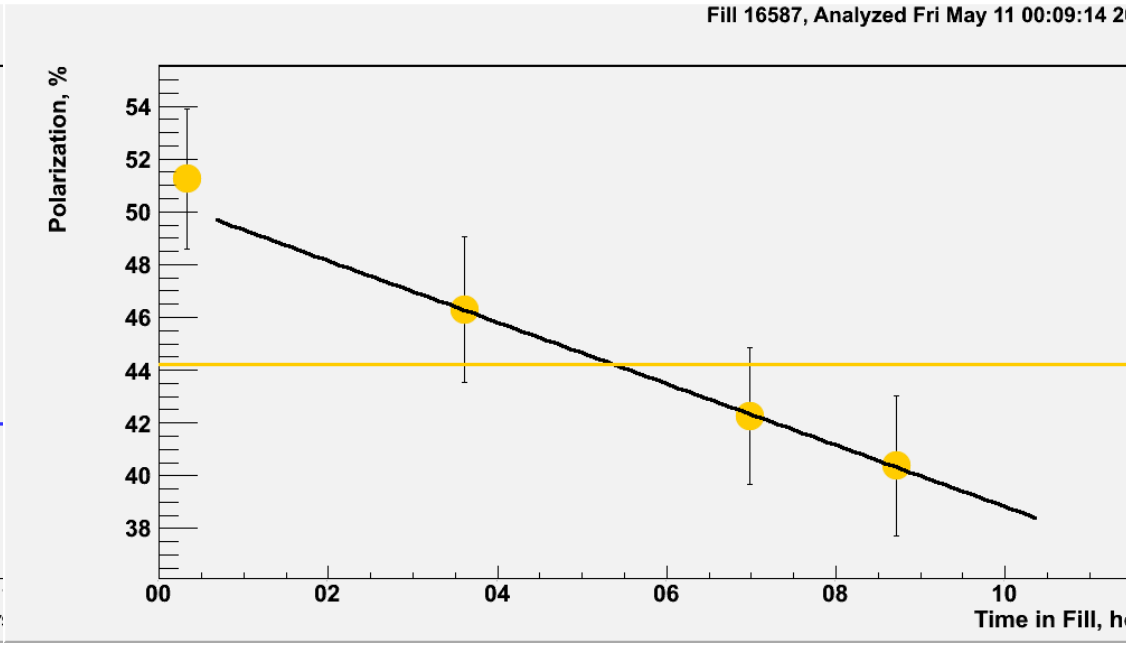
Select

Fills selected: 142

Fill	Type	Flattop, GeV	Polarization, % In collisions	Polarization, %	Polarization, % In collisions	Polarization, %	Polarization, % H-jet	Polarization, % B1U	Polarization, % B2D	R_ Ho pro
16299	phys	100	**77.50 ± 8.17**	74.23 ± 6.62	**67.75 ± 5.51**	67.87 ± 4.93		69.78 ± 2.12	80.50 ± 10.09	0.09 ±
16300	phys	100	**76.94 ± 6.93**	74.74 ± 6.04	**69.10 ± 4.94**	71.42 ± 4.49		69.04 ± 1.91	74.72 ± 3.50	-0.03 ±
16302	phys	100	**63.86 ± 6.09**	65.24 ± 5.99	**73.04 ± 5.15**	70.80 ± 4.48		61.71 ± 1.84	62.23 ± 2.99	-0.08 ±
16308	phys	100	**63.98 ± 6.53**	65.48 ± 6.37	**73.57 ± 5.49**	69.12 ± 4.49		61.00 ± 3.46	63.42 ± 3.68	-0.01 ±
16310	phys	100	**72.18 ± 7.57**	68.75 ± 6.43	**67.24 ± 5.43**	67.10 ± 4.54		66.31 ± 3.95	62.33 ± 3.04	0.12 ±
16340	phys	100	**70.50 ± 10.59**	68.81 ± 7.53	**67.18 ± 5.95**	62.17 ± 4.53		64.73 ± 6.09	65.39 ± 6.80	0.19 ±

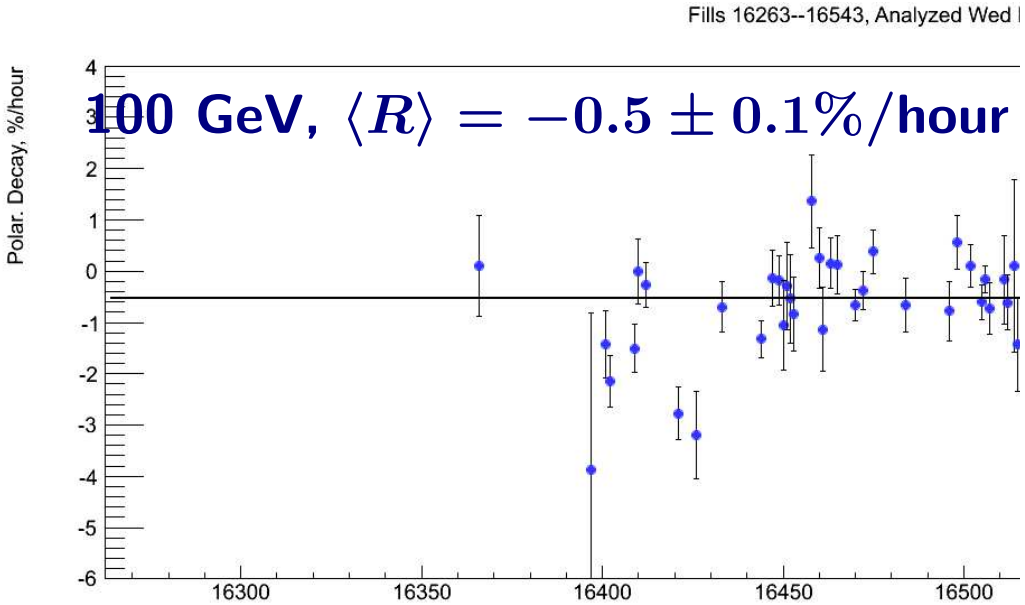
Polarization Decay

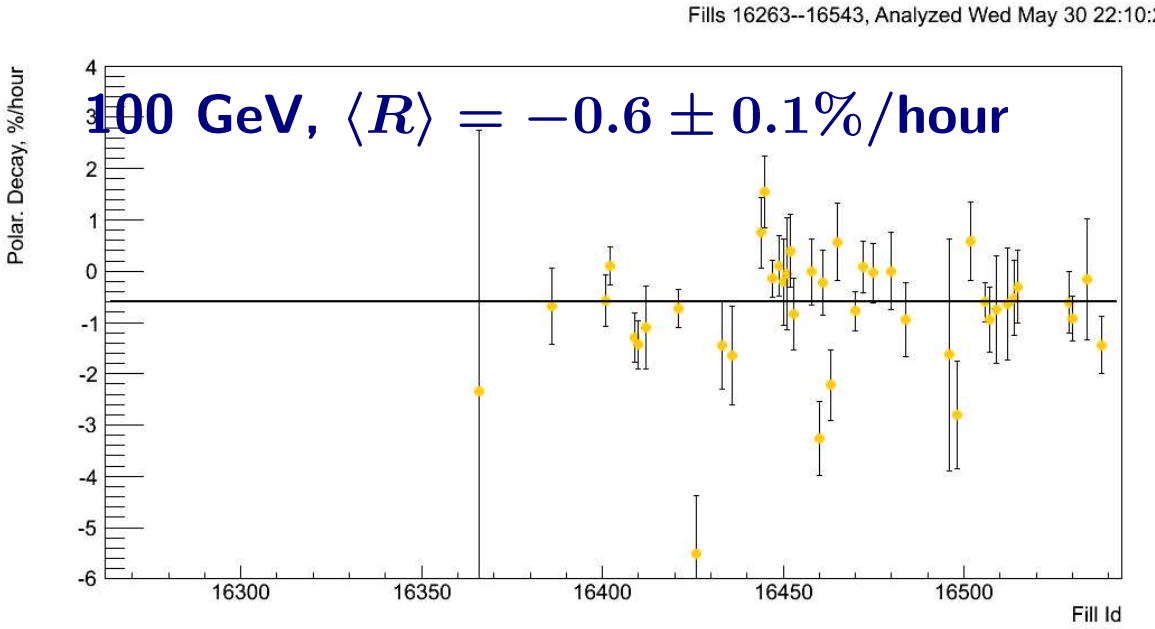


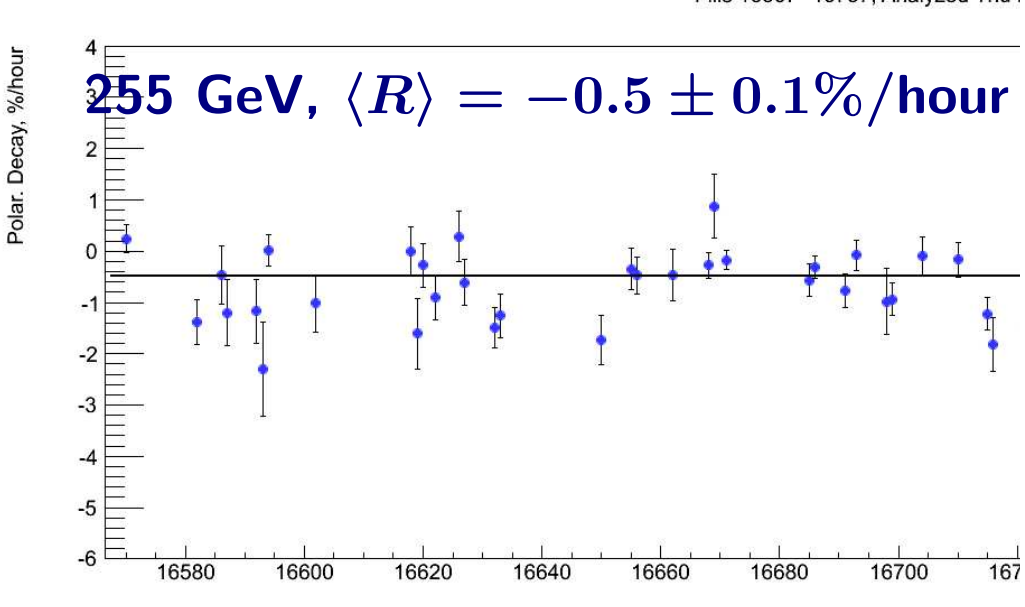


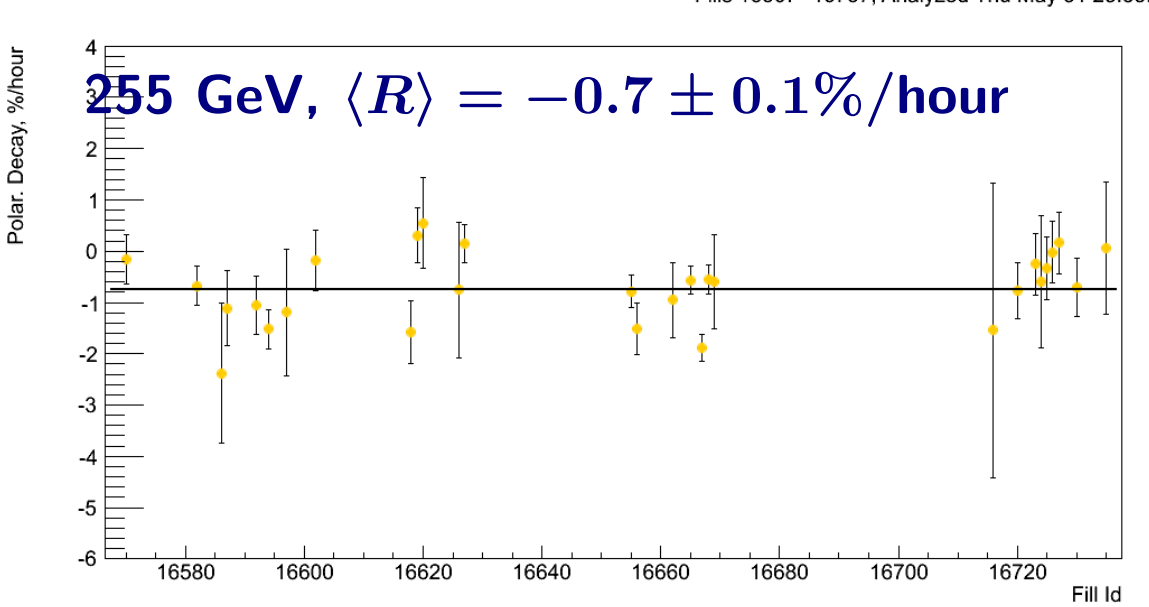
- Polarization significantly decreases during the fill
- The experiments may want to reweight individual fills according to their triggers, prescales, . . .
- In addition to intensity average P we shall provide a pair $(P_0, \frac{dP}{dt})$

Polarization Decay









- **Run 11:** $\langle R \rangle = -0.3 \pm 0.1\%$/hour (blue), $\langle R \rangle = -0.8 \pm 0.1\%$/hour (yellow)

Summary and Plans

- **Polarimeters performed well in Run 12**
  - Higher average H-jet intensity $\rightarrow$ decreased stat. uncertainty
  - Data cleaned up by removing channels affected by RF noise
  - Ready to report two numbers instead of average polarization per fill for Run 12 and 11
  - Fill by fill results available online at

    `http://www.phy.bnl.gov/cnipol/fills/`

- **Plan for Run 13**
  - **Accelerator complex:** Polarized source upgrade
    ~ 10x intensity, $\sim +5\%$ polarization
    - Consider Si detectors with smaller area
  - **RHIC Polarimeters:** Test new 12-bit FADC VME based readout electronics (250 MHz) in real environment
    - Waveform analysis algorithms can be also improved
    - Increase the dynamic range for H-jet by rearranging detectors

Polarimetry Group in Run 12

Igor Alekseev
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Polarimetry group web page:

`https://wiki.bnl.gov/rhicspin/Polarimetry`